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Bescheinigung | Certificate | Attestation

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The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

99303738.1

PRIORITY DOCUMENT

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Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
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METHOD AND APPARATUS FOR EPITAXIALLY GROWING A MATERIAL ON A SUBSTRATE

The invention relates to a method and apparatus for epitaxially growing a material on a substrate.

Conventional methods typically use a metalorganic chemical vapour phase deposition (MOCVD) epitaxial reactor. In such a reactor, the precursors containing the elements which are to be grown are supplied to a substrate such as a wafer supported on a wafer carrier which is heated. Heat is conveyed to the precursors which crack or dissociate into nascent atoms which then combine on the surface of the substrate. In a typical example, trimethyl gallium and ammonia, together with hydrogen, are supplied to the substrate to form a gallium nitride layer.

A problem with known reactors is that the precursors have cracking temperatures which are much higher than the ideal growth temperatures. For example, ammonia typically requires temperatures up to 1000°C or more to crack efficiently while the ideal growth temperature is in the order of 650°C.

The problem with conventional reactors is that the wafer carrier will maintain the substrate at a relatively constant temperature which typically will be chosen to be the ideal growth temperature, in this example 650°C. As a result, the ammonia is only very inefficiently cracked.

In accordance with one aspect of the present invention, a method of epitaxially growing a material on a substrate comprises supplying precursors separately to a growth region on the substrate; and separately heating the precursors to their respective decomposition temperatures at or adjacent the growth region to generate species which combine at the growth region.

In accordance with a second aspect of the present invention, apparatus for epitaxially growing a material on a substrate comprises a chamber containing a substrate support, the chamber having a first inlet for supplying a

first precursor and a second inlet, separate from the first inlet, for supplying a second precursor; and first and second heating means for separately heating the first and second precursors to their respective decomposition temperatures at or adjacent the growth region to generate species which combine at the growth region.

In contrast to the known methods, we separately heat the precursors to their respective decomposition temperatures at or adjacent the growth region. In this way, each precursor can be heated to its most efficient cracking temperature, while carrying out this process adjacent to the growth region minimises the risk of nascent atoms recombining before reaching the substrate surface.

In the preferred example, one of the precursors is heated to its cracking temperature by heating the substrate. In this preferred example, another of the precursors is heated to its cracking temperature at a location adjacent the growth region. Thus, the substrate could be heated in the range 550-800°C, for example 650°C, while the other precursor is heated to a temperature in the range 1000-1100°C.

Preferably, the second inlet is formed in a supply conduit located adjacent to the substrate support. This provides a convenient way of bringing the second precursor close to the substrate.

The second inlet can take a variety of forms including for example a circular hole or the like but is preferably in the form of an elongate slot.

The second heating means is conveniently provided in or adjacent the slot although it could be spaced upstream of the slot.

The supply conduit will typically be made of a refractory material such as quartz, SiN or alumina while the second inlet preferably defines a jet aperture having a transverse dimension of for example 2mm.

Preferably, the second inlet defines an outlet direction for the precursor which is at an acute angle to

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Bezeichnung der Erfindung:
Title of the invention:
Titre de l'invention:
Method and apparatus for epitaxially growing a material on a substrate

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the substrate support since this will create a venturi effect which will encourage other gases such as hydrogen supplied from a remote source to pass under the conduit.

The second heating means is typically in the form of a heating wire made for example of iron, platinum or their alloys and will typically be coiled.

In most applications, it is desired to extend the epitaxial growth to a relatively large region of the substrate. This is most conveniently achieved by moving the growth region across the substrate, for example by providing means for causing relative movement between the substrate support and at least one of the inlets.

Furthermore, the invention is not limited to the provision of a single growth region upon a single substrate. For example, a plurality of supply conduits may be provided for supplying the same or different precursors to growth regions on the substrate, the conduits and substrate support being relatively movable to bring the conduits into alignment with different growth regions.

Some examples of methods and apparatus according to the invention will now be described with reference to the accompanying drawings, in which:-

Figure 1 is a schematic cross-section through the apparatus of a first example;

Figure 2 is an enlarged, cross-section through part of the apparatus shown in Figure 1;

Figure 3 is an underneath plan of part of the apparatus shown in Figure 1;

Figure 4 is a schematic, cross-section through the apparatus of a second example; and,

Figure 5 is a schematic plan of a second example.

The reactor shown in Figure 1 comprises a reaction chamber 4 within which is provided a susceptor 3 which supports a wafer carrier 2. In Figure 1, a wafer 1 is shown in place on the wafer carrier 2. The substrate carrier 3 may be a graphite block which is heated in a

conventional manner by for example induction, infrared or resistance heating methods.

A first inlet 6 is provided in a side wall of the reaction chamber 4 while a gas deflector 7 is mounted within the reaction chamber to direct precursor gases 5, entering through the inlet 6, towards the wafer 1.

An injector conduit 9 extends transversely across the reaction chamber 4 and is in the form of a refractory tube of for example quartz having an elongate slot 10 forming a jetting aperture extending along its length above the wafer carrier 2 (see Figure 2).

A straight wire or coil 11 is supported within the slot 10 to form a heating element.

In use, a substrate 1 is placed on the substrate support 2, the reaction chamber 4 is closed and then the pressure within the chamber adjusted as appropriate, typically in the range 5-1000 torr. Typically, the wafer material is chosen to promote epitaxial growth of the material and can include sapphire, GaN, GaAs, SiC or ZnO.

One or more reactive precursor gases 5 are introduced into the chamber through the inlet 6. Examples of the reactive gases include trimethyl gallium (for Ga deposition), trimethyl indium (for indium deposition) and so on depending upon the required composition of the deposited layer. Such a mixture may also contain precursors for semiconductor dopants. A gas such as hydrogen is also added to the mixture 5 to react with the radicals produced on dissociation of the precursor.

The substrate carrier 3 is heated such that the substrate 1 and the substrate support 2 are also heated due to their proximity to the substrate carrier 3 attaining a suitable growth temperature for the substrate 1 i.e. a temperature at which the precursor 5 introduced through the inlet 6 will most efficiently crack. A suitable temperature for the growth of GaN is in the range 600-800°C.

A second precursor gas 8, in this example ammonia, is supplied along the conduit 9 under pressure so that it exits through the jetting slot 10 past the heating wire 11. The wire 11 is heated to a temperature typically in the range 1000-1100°C suitable for achieving optimum cracking of ammonia to generate N atoms. It will be noted in Figure 2 that the slot 10 is angled relative to a normal to the wafer 1 so as to cause gases introduced through the inlet 5 to be drawn under the conduit 9 as shown by an arrow 30 as a result of a venturi effect.

The precursor gas 5, upon reaching the substrate 1, will be cracked in a conventional manner and the resultant species, for example Ga atoms, will combine with nascent nitrogen from the gas 8 to initiate epitaxial growth of gallium nitride on the substrate 1.

The wire 11 is preferably made from a catalytic material such as platinum and will be heated by using electrical resistance heating if the element takes the form of a filament wire. The distance between the wire 11 and the substrate 1 is small to allow the maximum quantity of cracked product from the precursor 8 to react with the precursor mixture 5 at the substrate surface. This optimum distance is also influenced by the flow rate of the mixture 5, typical conditions for ammonia in the production of GaN being a distance of around 5mm for a flow velocity of $0.35 ms^{-1}$.

In order to control the area of growth, the substrate support 2 is movably mounted on the substrate support 3 and can be moved (by means not shown) in the directions indicated by an arrow 31 beneath the conduit 9.

This process can then be repeated to enable further layers to be laid down on the wafer so producing multi-layered wafers containing materials of dissimilar dimensions, dopants or compositions.

Waste gases finally exit through an outlet 33.

An application for this invention is the production of microwave and optoelectronic devices. These devices are

built up layer upon layer from different materials with different electrical properties. The configuration of these layers determines whether the device is for microwave or light emission i.e. a Field Effect Transistor or a Light Emitting Diode. To achieve optimum performance the layers have to be grown where possible at the most ideal temperature. This temperature will vary depending upon the material used and the device being fabricated. The advantage of this invention is that the growth temperature of the material is not compromised by the necessity to have a high temperature to crack the precursor materials such as ammonia. Advantageously the invention also provides the possibility of using precursors that would otherwise be incompatible in the gas phase such as dicyclopentadienylmagnesium and ammonia.

A second example of the present invention is shown in Figure 4. In this case the reaction chamber 4′ comprises a tubular quartz outer cell 60 of substantially circular cross-section attached to a cell block end 61. Within the outer cell 60 is positioned an inner cell 65 of substantially square tubular section. A removable molybdenum carrier plate 66 is seated within inner cell 65. The carrier plate 66 extends along the base of the inner cell 65. The substrate carrier 3 equipped with heating means (not shown) rests upon the carrier plate 66. Additionally a self-supporting quartz gas deflector 7′ is also positioned upon the carrier plate 66. An exit vent 67 for the gases is provided through the cell block end 61. The injector conduit 9 enters the cell through the cell block end 61 and in contrast to the example shown in Figure 1, lies in a direction approximately parallel to that of the mass gas flow (indicated by an arrow 68 in Figure 4) and extends only halfway across the substrate 1. The elongate slot 10 and heating element 11 are of appropriate dimensions to produce deposition in a region between the outer edge and centre of the substrate. In this case the substrate support 2 is positioned within a recess 70

provided in the substrate carrier 3. The substrate support itself also contains a recess 71 into which the substrate 1 is placed during deposition. The dimensions of both recesses and the substrate are such that the upper surfaces of the substrate 1 and substrate support 2 are substantially flush with that of the substrate carrier 3. The substrate support is mounted upon a shaft 75 which enters the cell from beneath and passes through holes in the substrate carrier 3, the carrier plate 66 and the cell walls 60, 65. The cell walls 60, 65 are equipped with suitable gas seals to maintain the cell pressure. The lower end of the shaft is attached to a motor 80 or other suitable rotation means.

During operation both the outer and inner cells are evacuated in order to reduce the pressure differential across the inner cell walls 65. As in the previous example, one or more precursor gases enter the inner cell from an inlet on the right of the figure (not shown). Deposition of the material also occurs in a similar manner. However, here the rotation of shaft 75 by the motor (shown by arrow 76 in Figure 4) causes relative rotational rather than reciprocal motion with respect to the injector conduit.

In this example the injector conduit 9 and shaft 75 are detachable from the apparatus, allowing the slidable removal of the carrier plate 66, gas deflector 7′ and substrate carrier assembly.

Figure 5 shows apparatus for growth of materials upon a plurality of substrates 17 mounted upon a heated susceptor 18 in a chamber (not shown). One or both of the conduits 19 and the susceptor 3 are rotatable. Layers of a semiconducting wafer may be deposited sequentially using a plurality of precursor supply conduits 19, similar to the conduit 9, radiating from the centre of the susceptor. In one example, the supply conduits are grouped as shown so as to bring precursors for both reacting species to a single region simultaneously. Substrates 17 are successively

brought into close proximity to supply conduits 19 by relative movement of the conduits 19 and substrates 17.

In an alternative example, conduits 19 may individually supply precursors sequentially to the growth region, rapid relative movement between each substrate and each precursor conduit ensuring that only a short time elapses between the delivery of each species. In a further example, hydrogen is introduced to the system at the centre of the substrate support, flowing radially outwards rather than being supplied directly with one of the precursors.

CLAIMS

1. A method of epitaxially growing a material on a substrate, the method comprising supplying precursors separately to a growth region on the substrate; and separately heating the precursors to their respective decomposition temperatures at or adjacent the growth region to generate species which combine at the growth region.

2. A method according to claim 1, wherein the species are chosen from the Group III and Group V elements.

3. A method according to claim 2, wherein the species comprise Gallium and nitrogen.

4. A method according to claim 3, wherein one of the precursors is ammonia.

5. A method according to any of the preceding claims, wherein the substrate comprises a semiconductor such as Gallium-Arsenide.

6. A method according to any of the preceding claims, wherein one of the precursors is heated to its cracking temperature by heating the substrate.

7. A method according to claim 6, wherein the substrate is heated to the cracking temperature of the precursor with the lower cracking temperature.

8. A method according to claim 6 or claim 7, wherein the substrate is heated to a temperature in the range 550-800°C.

9. A method according to any of the preceding claims, wherein one of the precursors is heated to its cracking temperature at a location adjacent the growth region.

10. A method according to claim 9, wherein the precursor is heated to a temperature in the range 1000-1100°C.

11. A method according to any of the preceding claims, further comprising moving the growth region across the substrate.

12. Apparatus for epitaxially growing a material on a substrate, the apparatus comprising a chamber containing . substrate support, the chamber having a first inlet f

supplying a first precursor and a second inlet, separate from the first inlet, for supplying a second precursor; and first and second heating means for separately heating the first and second precursors to their respective cracking/ decomposition temperatures at or adjacent the growth region to generate species which combine at the growth region.

13. Apparatus according to claim 12, wherein the second inlet is formed in a supply conduit located adjacent the substrate support.

14. Apparatus according to claim 13, wherein the second inlet is in the form of an elongate slot.

15. Apparatus according to claim 13 or claim 14, wherein the second heating means is provided in or adjacent the slot.

16. A method according to any of claims 12 to 15, wherein the second heating means is in the form of a heating wire.

17. Apparatus according to any of claims 12 to 16, wherein the first heating means is located at a position to heat the substrate support.

18. Apparatus according to any of claims 12 to 17, further comprising means for causing relative movement between the substrate support and at least one of the inlets.

19. Apparatus according to claim 18, when dependent on at least claim 13, wherein a plurality of supply conduits are provided for supplying the same or different precursors to growth regions on the substrate, the conduits and substrate support being relatively movable to bring the conduits into alignment with different growth regions.

20. Apparatus according to claim 18 wherein the relative movement between the substrate support and at least one of the inlets is in a transverse manner.

21. Apparatus according to claim 18 wherein the relative movement between the substrate support and at least one of the inlets is in a rotational manner.

ABSTRACT

METHOD AND APPARATUS FOR EPITAXIALLY GROWING A MATERIAL ON A SUBSTRATE

A method of epitaxially growing a material on a substrate (1). The method comprises supplying precursors separately to a growth region on the substrate (1); and separately heating the precursors to their respective decomposition temperatures at or adjacent the growth region to generate species which combine at the growth region.

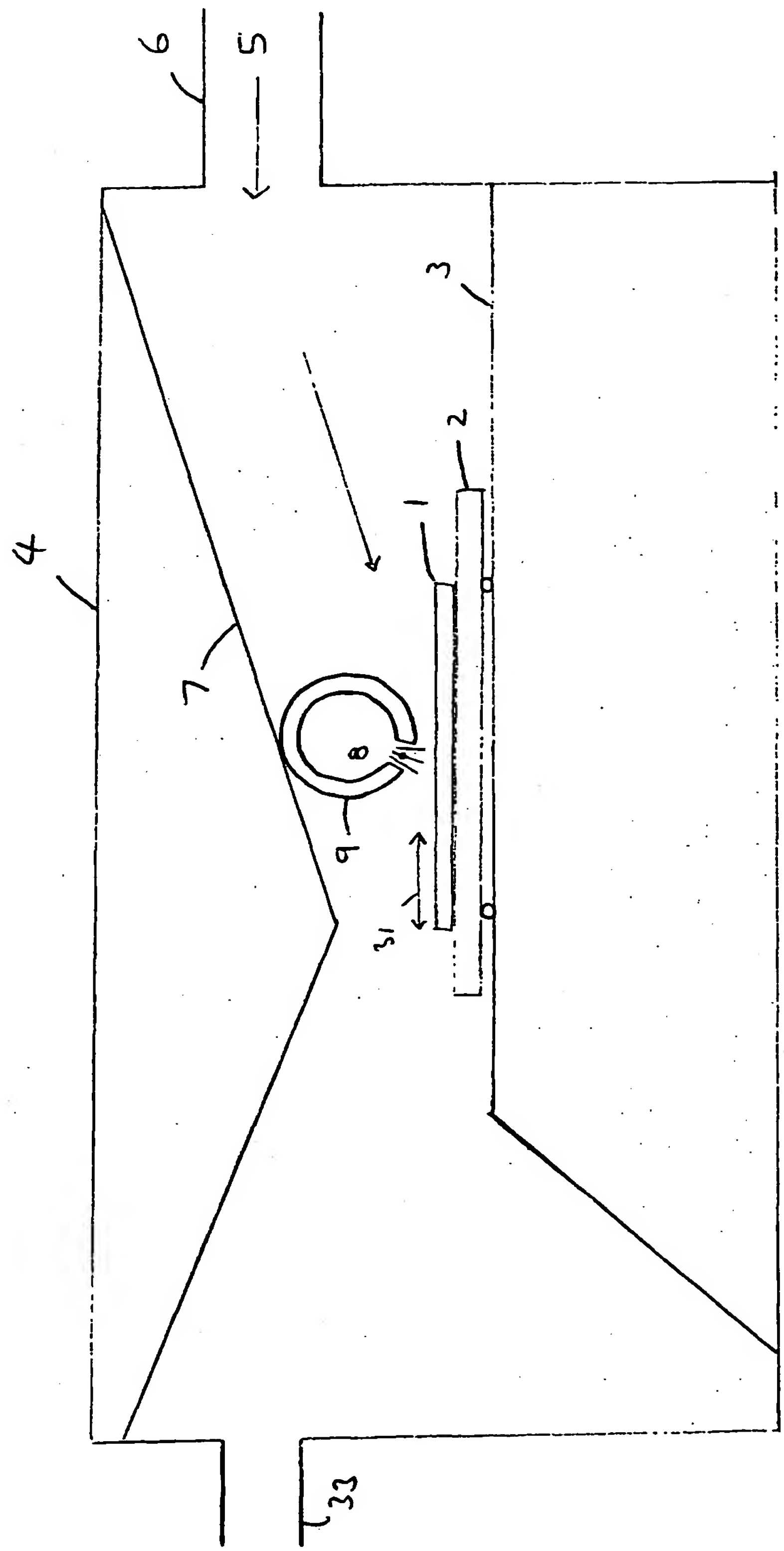
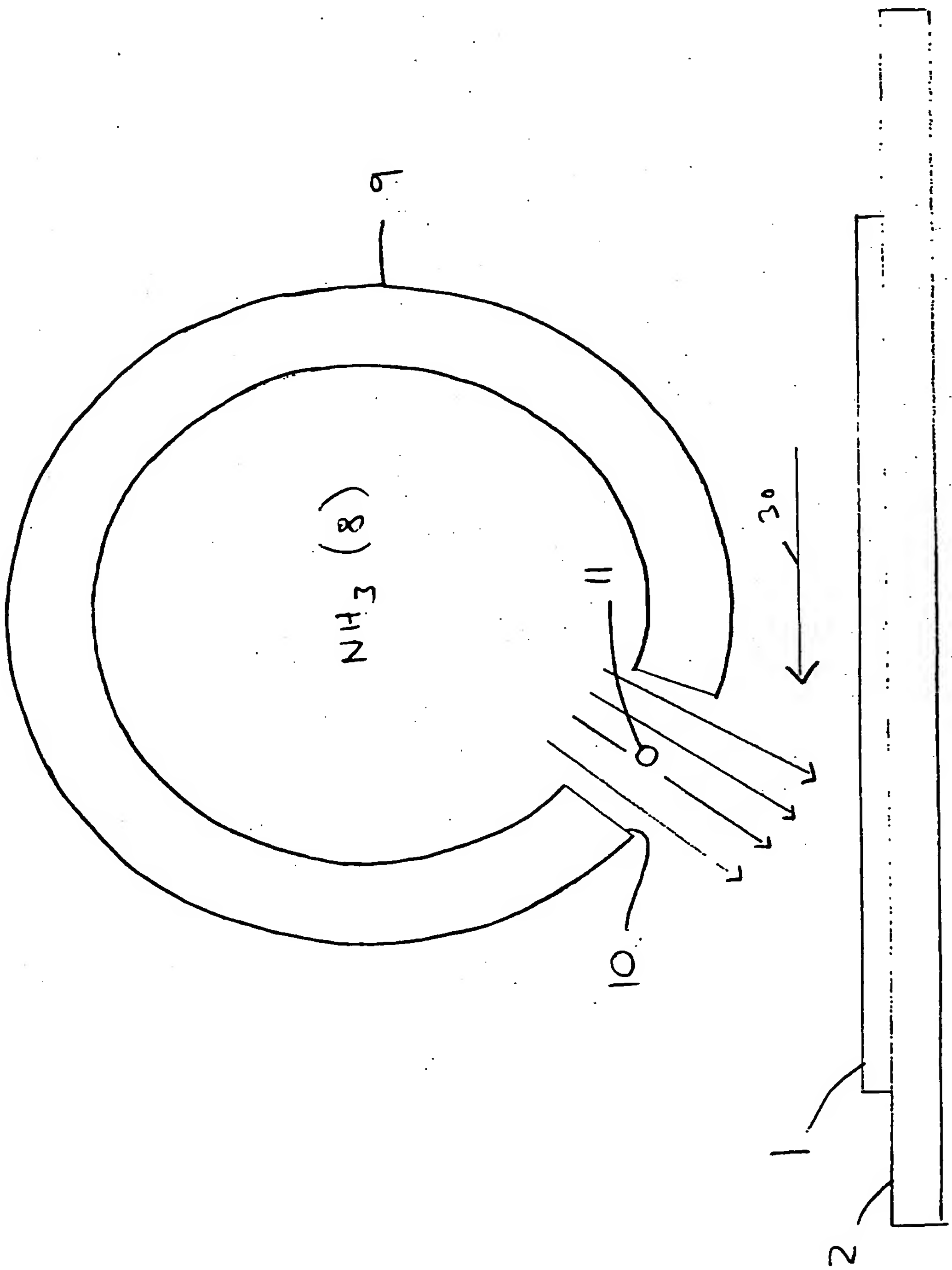


Fig 1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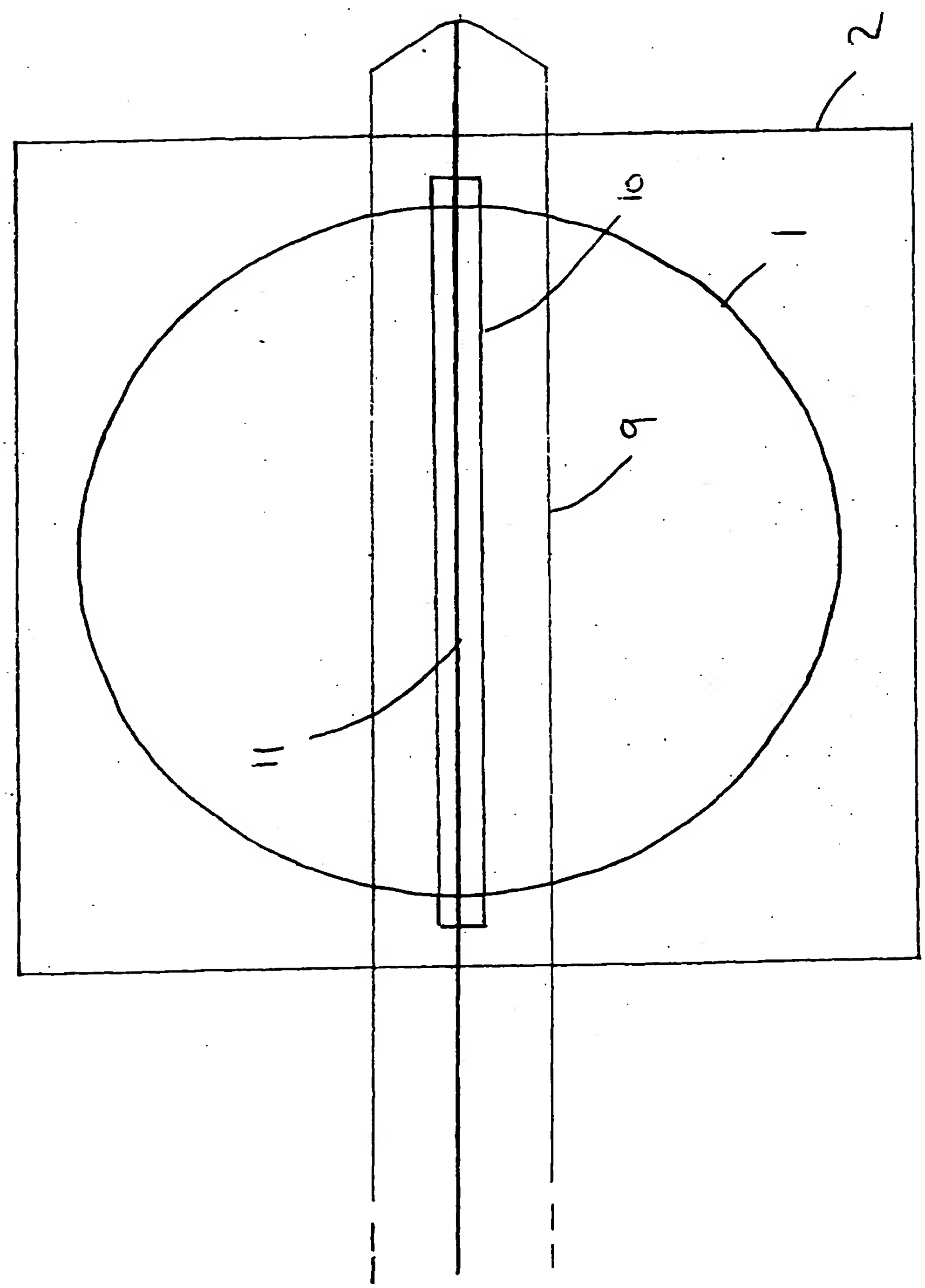

FIG. 3

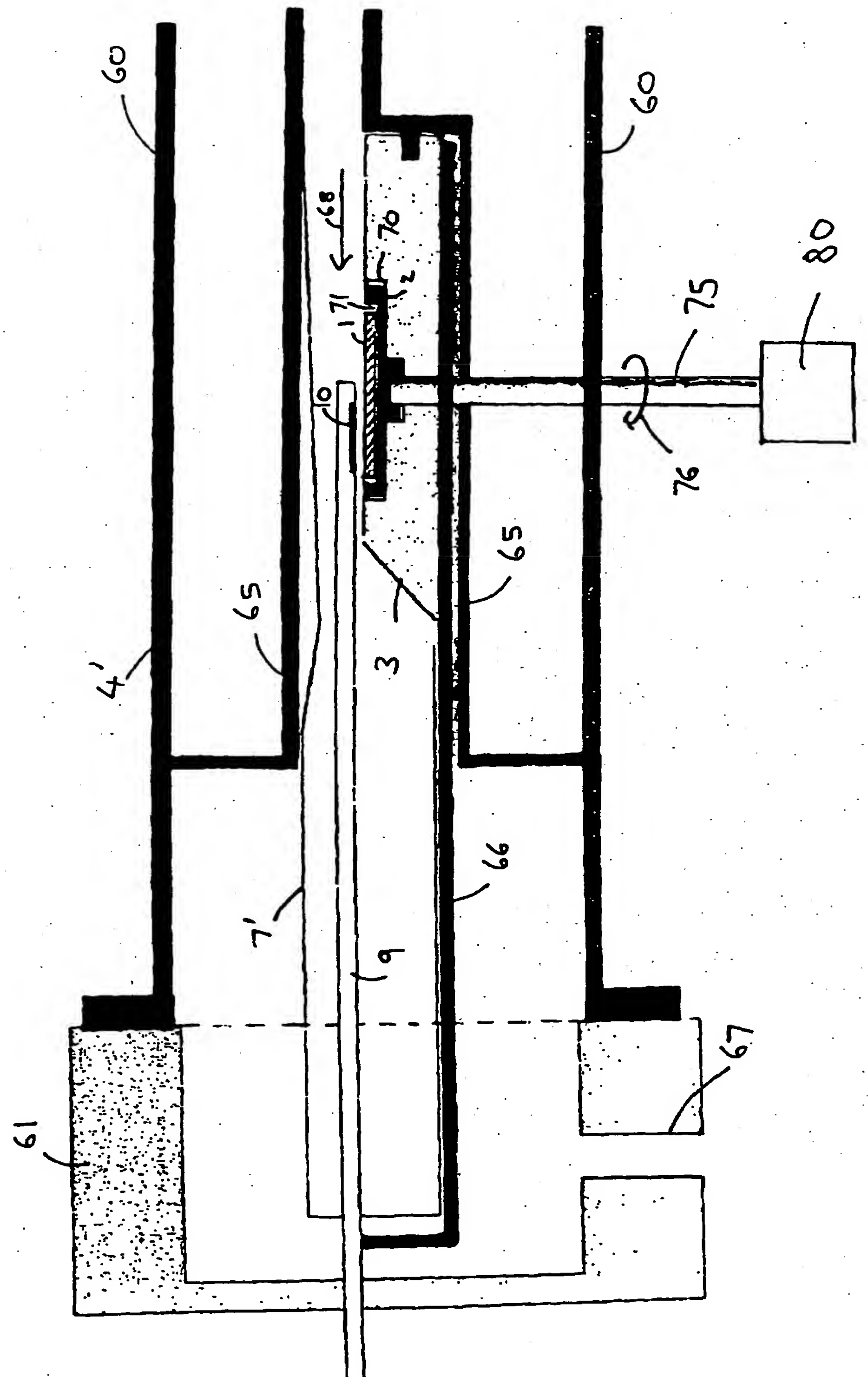

FIG. 4

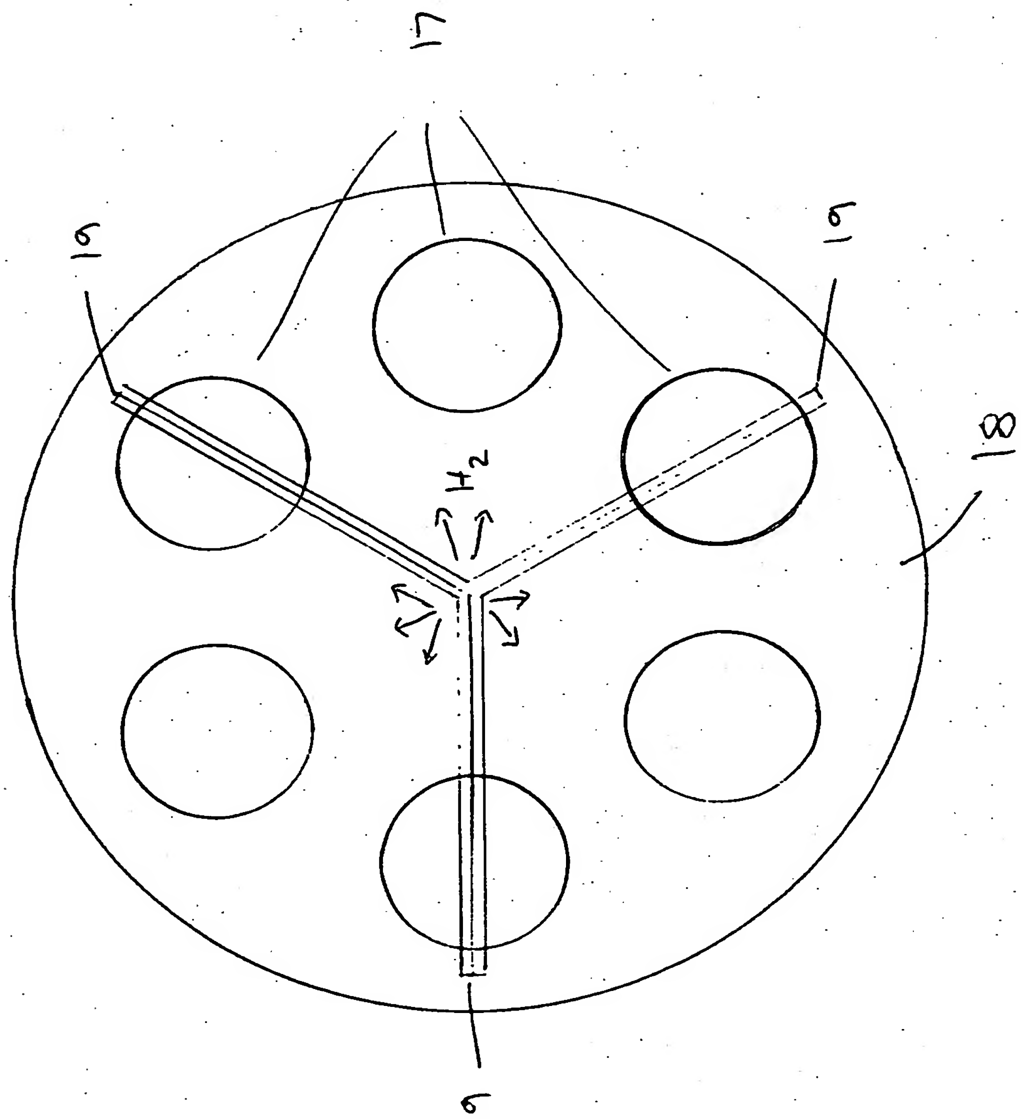

FIG. 5